

PATENT APPLICATION

Title: Clamp for Feedwater Sparger End Bracket Assemblies and Method of Preventing Separation of Feedwater Sparger End Bracket Assemblies

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CROSS-REFERENCE TO RELATED PATENT APPLICATION

1 This application claims priority from prior provisional patent application Serial No.
2 60/264,965 filed January 30, 2001, the entire disclosure of which is incorporated herein by
3 reference.

4 BACKGROUND OF THE INVENTION

5 Field of the Invention:

6 The present invention relates to feedwater spargers in boiling water reactors and,
7 more particularly, to clamps for the end bracket assemblies of feedwater spargers and to
8 methods of preventing separation of feedwater sparger end bracket assemblies.

9 Brief Discussion of the Related Art:

10 Conventional boiling water reactors typically include a reactor vessel, a shroud
11 disposed within the reactor vessel and a fuel assembly within the shroud. Feedwater
12 enters the reactor vessel via a feedwater inlet or nozzle and is distributed circumferentially
13 within the reactor vessel by a feedwater sparger disposed in the reactor vessel between
14 the shroud and the reactor vessel wall. The feedwater sparger comprises a ring-shaped
15 pipe or conduit for carrying the feedwater and having an end attached to a sparger end
16 plate via a feedwater sparger end weld, the sparger end plate and conduit end attached
17 thereto defining an end of the feedwater sparger. A feedwater sparger end bracket
18 assembly couples the end of the feedwater sparger to the reactor vessel wall in spaced

relation therewith. The feedwater sparger end bracket assembly normally comprises an attachment plate connected to the sparger end plate via a weld, and the structural components of the feedwater sparger end bracket assembly are ordinarily connected to one another via one or more additional welds. The attachment plate and the sparger end plate attached thereto form a sparger/bracket junction by which the conduit of the feedwater sparger is connected to the feedwater sparger end bracket assembly. The feedwater sparger end bracket assembly defines a load path for transferring loads from the feedwater sparger to a reactor vessel attachment fitting attached to the reactor vessel wall and to which the feedwater sparger end bracket assembly is connected. The structural adequacy of feedwater sparger end welds and feedwater sparger end bracket assembly welds has been questioned in light of cracking identified in these welds. In particular, the weld between the attachment plate and the sparger end plate and the weld between the sparger end plate and the conduit end are primarily fillet welds, and reactor coolant can infiltrate or get between the structural components joined by these fillet welds so that the roots of the fillet welds are exposed to reactor coolant. The geometry of the fillet welds presents a crevice where corrosive products can concentrate and accumulate over time, thereby producing stress corrosion cracking.

Cracks large enough to allow significant flow of feedwater from the feedwater sparger may result in direct impingement of the relatively colder feedwater on the reactor vessel wall, causing thermal shock and cracking of the cladding on the interior surface of the reactor vessel wall. In addition, the feedwater sparger end bracket assemblies usually

1 carry an installation preload, and this preload is undesirably compromised or lost in the
2 event of cracking of the feedwater sparger end welds and/or the feedwater sparger end
3 bracket assembly welds, especially in the event of cracking which results in complete
4 detachment of the feedwater sparger end bracket assembly from the feedwater sparger.

5 An example of feedwater sparger end bracket assemblies that have an installation preload
6 are those associated with feedwater spargers that are sprung into place during installation,
7 such as to maintain contact between flow baffles of the feedwater spargers and the
reactor vessel wall. The flow baffles, which are ordinarily located at the feedwater nozzles
in the reactor vessel, must remain essentially in contact with the reactor vessel wall to
effectively eliminate thermal shock conditions at the feedwater nozzles. To assure this, the
feedwater spargers are sprung into place at installation, resulting in an installation preload
on each feedwater sparger end bracket assembly of about eight thousand pounds. In the
event of complete weld failure causing the feedwater spargers to become completely
detached from the feedwater sparger end bracket assemblies, the installation preload is
lost and the feedwater spargers will not perform as designed.

16 Mechanical solutions to the problems of cracked feedwater sparger end welds and
17 feedwater sparger end bracket assembly welds encounter numerous obstacles in that
18 mechanical devices attached to the ends of the feedwater spargers and the feedwater
19 sparger end bracket assemblies must be capable of maintaining the installation preload
20 in the event of weld failure. Mechanical devices must be capable of balancing all loads
21 and moments to which they are subjected, and particularly must react to the loads and

1 moments created when there is a complete through wall crack of the feedwater sparger
2 end welds and/or the welds of the feedwater sparger end bracket assemblies. Another
3 deterrent to the use of mechanical devices to address the problems of weld failure in the
4 ends of feedwater spargers and in feedwater sparger end bracket assemblies is that
5 existing feedwater sparger end bracket assemblies often have different structural
6 dimensions and/or components. The use of mechanical devices with feedwater sparger
7 end bracket assemblies is thusly impeded by the difficulty involved in designing an
8 essentially standard mechanical device for use with different feedwater sparger end
9 bracket assemblies. A further impediment to the use of mechanical devices in response
10 to cracking of feedwater sparger end welds and feedwater sparger end bracket assembly
11 welds is the need for the mechanical devices to be installed using equipment or tooling
12 operated from a location remote from the reactor vessel.

SUMMARY OF THE INVENTION

14 Accordingly, it is a primary object of the present invention to overcome the problems
15 associated with cracking of feedwater sparger end welds and feedwater sparger end
16 bracket assembly welds.

17 Another object of the present invention is to utilize a clamp to prevent separation of
18 feedwater sparger end bracket assemblies.

1 A further object of the present invention is to utilize a clamp to prevent separation
2 of a feedwater sparger end from a feedwater sparger end bracket assembly welded to the
3 feedwater sparger end.

4 The present invention has as another object to constrain a feedwater sparger end
5 bracket assembly from separation in horizontal, vertical and radial directions.

6 It is also an object of the present invention to constrain a feedwater sparger end
7 against separation from a feedwater sparger end bracket assembly in horizontal, vertical
8 and radial directions.

9 An additional object of the present invention is to avoid direct impingement of
10 feedwater from a feedwater sparger on the reactor vessel wall in the event of cracking of
11 a feedwater sparger end weld and/or a feedwater sparger end bracket assembly weld.

12 Yet another object of the present invention is to maintain the preload of a feedwater
13 sparger end bracket assembly in the event of failure of a feedwater sparger end weld
14 and/or a feedwater sparger end bracket assembly weld.

15 Still a further object of the present invention is to balance loads and moments on a
16 clamp for a feedwater sparger end bracket assembly in the event of failure of a feedwater
17 sparger end weld and/or a feedwater sparger end bracket assembly weld.

18 The present invention has as an additional object to adapt a clamp for installation
19 on feedwater sparger end bracket assemblies of various structural dimensions and/or
20 components.

1 Moreover, it is an object of the present invention to utilize a clamp to provide an
2 alternate load path for loads from a feedwater sparger to a reactor vessel attachment
3 fitting.

4 Some of the advantages of the present invention are that the clamp can be
5 adjustably tightened on the feedwater sparger end bracket assembly; the clamp encloses
6 the feedwater sparger end bracket assembly; the clamp holds the feedwater sparger and
7 the feedwater sparger end bracket assembly together in the event of weld failure in any of
8 the welds of the feedwater sparger and/or the feedwater sparger end bracket assembly;
9 the clamp incorporates corrosion resistant materials; the clamp does not require welding
10 to the feedwater sparger end, to the feedwater sparger end bracket assembly or to the
11 reactor vessel; thermal shock and cracking of the cladding on the interior surface of the
12 reactor vessel wall are avoided; the moment created on the clamp in the event of through
13 wall cracking of a feedwater sparger end weld and/or a feedwater sparger end bracket
14 assembly weld is balanced; shims and/or spacers can be used to easily adapt the clamp
15 for installation on feedwater sparger end bracket assemblies having different structural
16 dimensions and/or components; clearances between the clamp and the feedwater sparger
17 and/or between the clamp and the feedwater sparger end bracket assembly can be limited
18 or controlled to ensure a tight fit; proper operation of flow baffles of the feedwater spargers
19 is maintained; the clamp may be installed remotely; and the clamp may be used on both
20 originally installed feedwater sparger end bracket assemblies and replacement feedwater
21 sparger end bracket assemblies.

1 These and other objects, advantages and benefits are realized with the present
2 invention as generally characterized in a clamp for installation on a feedwater sparger end
3 bracket assembly connected to a conduit of a feedwater sparger at a sparger/bracket
4 junction in a boiling water reactor vessel. The clamp includes an upper clamp member for
5 being assembled over a top of the feedwater sparger end bracket assembly, a lower clamp
6 member for being assembled over a bottom of the feedwater sparger end bracket
7 assembly and a connector securing the upper and lower clamp members to one another.
8 The upper clamp member includes a compartment receiving an upper portion of the
9 sparger/bracket junction, and the lower clamp member includes a compartment receiving
10 a lower portion of the sparger/bracket junction. Each compartment comprises opposing
11 walls constraining the sparger/bracket junction in a first direction tangential or horizontal
12 to the boiling water reactor vessel. Each clamp member includes an inner shoulder along
13 an inner side of the feedwater sparger end bracket assembly and an outer shoulder along
14 an outer side of the feedwater sparger end bracket assembly for constraining the
15 feedwater sparger end bracket assembly between the inner and outer shoulders in a
16 second direction radial to the boiling water reactor vessel. The upper clamp member
17 includes a lower surface along the top of the feedwater sparger end bracket assembly.
18 The lower clamp member includes an upper surface along the bottom of the feedwater
19 sparger end bracket assembly, and the feedwater sparger end bracket assembly is
20 constrained between the lower surface and the upper surface in a third direction vertical
21 to the boiling water reactor vessel. The upper clamp member further includes a recessed

lower surface along the top of the conduit of the feedwater sparger, and the lower clamp member further includes a recessed upper surface along the bottom of the conduit, the conduit being constrained in the third direction between the recessed lower and upper surfaces. Each clamp member includes a shear tab positioned to be disposed between the conduit of the feedwater sparger and a wall of the boiling water reactor vessel with a close fit. The shear tab balances moments and loads to which the clamp is subjected. The upper clamp member comprises an impingement shield extending downwardly therefrom toward the lower clamp member, and the lower clamp member comprises an impingement shield extending upwardly to meet the impingement shield of the upper clamp member. The impingement shields are disposed between the sparger/bracket junction and the wall of the boiling water reactor vessel and serve to isolate the sparger/bracket junction from the wall of the boiling water reactor vessel.

A method of preventing separation of a feedwater sparger end bracket assembly connected to a conduit of a feedwater sparger at a sparger/bracket junction in a boiling water reactor vessel is generally characterized in the steps of vertically separating an upper clamp member of a clamp from a lower clamp member of the clamp, locating the upper clamp member over a top of the feedwater sparger end bracket assembly, locating the lower clamp member over a bottom of the feedwater sparger end bracket assembly, moving the upper and lower clamp members toward one another to position an upper portion of the sparger/bracket junction within a compartment of the upper clamp member and to position a lower portion of the sparger/bracket junction within a compartment of the

1 lower clamp member, securing the upper and lower clamp members to one another, and
2 leaving the upper and lower clamp members in place to constrain the sparger/bracket
3 junction in a first direction, to constrain the feedwater sparger end bracket assembly in a
4 second direction, and to constrain the feedwater sparger end bracket assembly in a third
5 direction.

6 Other objects and advantages of the present invention will become apparent from
7 the following description of a preferred embodiment taken in conjunction with the
8 accompanying drawings, wherein like parts in each of the several figures are identified by
9 the same reference characters.

BRIEF DESCRIPTION OF THE DRAWINGS

10 Fig. 1 is a front perspective view depicting a portion of a reactor vessel of a boiling
11 water reactor and illustrating a feedwater sparger end bracket assembly attached to an end
12 of a feedwater sparger of the boiling water reactor.

13 Fig. 2 is an inner side view of the feedwater sparger end bracket assembly
14 illustrated in Fig. 1.

15 Fig. 3 is a front view of the feedwater sparger end bracket assembly illustrated in
16 Fig. 1.

17 Fig. 4 is a top view of the feedwater sparger end bracket assembly illustrated in Fig.

18 1.

1 Fig. 5 is an inner side perspective view of the feedwater sparger end bracket
2 assembly illustrated in Fig. 1 with the exception that the reactor vessel is not shown for
3 the sake of simplicity.

4 Fig. 6 is an inner side perspective view of an alternative feedwater sparger end
5 bracket assembly attached to an end of a feedwater sparger, with the reactor vessel not
6 being shown for the sake of simplicity.

7 Fig. 7 is a front perspective view of a clamp according to the present invention for
use on a feedwater sparger end bracket assembly.

8 Fig. 8 is a rear perspective view of the clamp illustrated in Fig. 7.

9 Fig. 9 is a front view of the clamp.

10 Fig. 10 is a top view of the clamp.

11 Fig. 11 is a rear view of the clamp.

12 Fig. 12 is an outer side view of the clamp.

13 Fig. 13 is a front perspective view of the clamp installed on the feedwater sparger
end bracket assembly of Fig. 1.

14 Fig. 14 is an inner side perspective view of the clamp installed on the feedwater
sparger end bracket assembly of Fig. 1.

15 Fig. 15 is a front view of the clamp installed on the feedwater sparger end bracket
assembly of Fig. 1.

Fig. 16 is a rear perspective view of the clamp installed on the feedwater sparger end bracket assembly of Fig. 1, with the reactor vessel not being shown for the sake of simplicity.

Fig. 17 is an outer side perspective view of the clamp installed on the feedwater sparger end bracket assembly of Fig. 1, with the reactor vessel not being shown for the sake of simplicity.

Fig. 18 is a bottom perspective view of the clamp installed on the feedwater sparger end bracket assembly of Fig. 1, with the reactor vessel not being shown for the sake of simplicity.

Fig. 19 is a bottom perspective view from a different angle of the clamp installed on the feedwater sparger and bracket assembly of Fig. 1, with the reactor vessel not being shown for the sake of simplicity.

Fig. 20 is a top sectional view depicting the clamp installed on the feedwater sparger end bracket assembly of Fig. 1.

DESCRIPTION OF THE PREFERRED EMBODIMENT

16 A fragmentary portion of a conventional boiling water reactor 10 is illustrated in Figs.
17 1-4 depicting a segment of a wall 11 of reactor vessel 12 and a length segment of
18 feedwater sparger 14 disposed within reactor vessel 12. The reactor vessel wall 11 is
19 generally cylindrical, and the complete reactor vessel wall extends upwardly, downwardly
20 and circumferentially beyond the edges or borders of the wall segment shown in the

drawings. A shroud (not shown) is disposed in the reactor vessel 12 in spaced relation with wall 11, and the feedwater sparger 14 is disposed in the circumferential gap or space between the shroud and the reactor vessel wall. The feedwater sparger 14 comprises a hollow conduit or pipe 15 that generally follows the circumferential curvature of the reactor vessel wall 11 and has a terminal end connected to a sparger end plate 16. The complete conduit 15 forms an annular or ring-shaped conduit or pipe in the reactor vessel 12 for carrying feedwater which enters the reactor vessel at one or more feedwater inlets or nozzles in communication with the lumen of conduit 15. The feedwater is distributed circumferentially within the reactor vessel 12 via interiorly directed outlet holes 17 in the conduit 15. A representative conduit 15 has concentric circumferential inner and outer side walls connected by planar top and bottom walls, with the holes 17 being formed in the inner side wall. The conduit 15 has a rectangular cross-sectional configuration with the major cross-sectional dimension thereof extending or oriented vertically in the reactor vessel 12 and the minor cross-sectional dimension thereof extending or oriented radially in the reactor vessel 12.

A representative sparger end plate 16 is planar and is of generally rectangular peripheral configuration with the major dimension thereof also extending or oriented vertically to close off the open end of conduit 15. The sparger end plate 16 is typically attached to the end of conduit 15 by a feedwater sparger end weld 18, and the conduit end and the sparger end plate attached thereto define an end of feedwater sparger 14. The sparger end plate 16 is connected to a feedwater sparger end bracket assembly 20

1 which, in turn, is connected to a reactor vessel attachment fitting 21 connected, typically
2 by welding, to reactor vessel wall 11. The feedwater sparger end bracket assembly 20
3 thusly couples the end of the feedwater sparger 14 to the reactor vessel 12 in spaced
4 relation with reactor vessel wall 11. Accordingly, there is a circumferential gap or space
5 between the feedwater sparger 14 and the reactor vessel wall 11 as best shown in Fig.
6 4.

7 As used herein, the terms "top", "bottom", "upper", "lower", "upward" and
8 "downward" are referenced in a vertical direction; the terms "inner" and "interior" refer to
9 a direction toward a central longitudinal axis of the reactor vessel; the terms "outer" and
10 "exterior" refer to a direction away from the central longitudinal axis of the reactor vessel;
11 the terms "front" and "forward" refer to a direction away from the conduit end; the terms
12 "back" and "rearward" refer to a direction toward the conduit end; the term "vertical" refers
13 to the direction of the central longitudinal axis of the reactor vessel; the term "radial" refers
14 to a direction radial to the reactor vessel wall; and the terms "horizontal" and "tangential"
15 refer to a direction transverse or perpendicular to the vertical and radial directions.

16 As shown in Figs. 1-5, the feedwater sparger end bracket assembly 20 for a
17 conventional boiling water reactor 10 ordinarily comprises an attachment plate 22
18 connected to sparger end plate 16 by a weld 23, a side plate 24 connected to attachment
19 plate 22 and extending transversely or perpendicularly therefrom in the forward direction,
20 and upper and lower bracket members 25 and 26, respectively, extending from attachment
21 plate 22 in the forward direction. A representative attachment plate 22 is planar and is of

1 generally rectangular peripheral configuration with the major dimension thereof extending
2 vertically within the reactor vessel 12 and the minor dimension thereof extending radially
3 in the reactor vessel 12. The peripheral configuration of the attachment plate 22 is larger
4 than the peripheral configuration of the sparger end plate 16 such that the sparger end
5 plate does not protrude beyond the periphery of the attachment plate. As best shown in
6 Fig. 4, it is typical for an inner side edge of attachment plate 22 to be spaced interiorly
7 beyond an inner side edge of sparger end plate 16. The attachment plate 22 is parallel
8 to the sparger end plate 16 and has a rearward surface in facing abutment with a forward
9 surface of the sparger end plate, the weld 23 being disposed between the abutting
10 surfaces of the attachment plate and the sparger end plate. The attachment plate and
11 sparger end plate may be provided with through holes to facilitate grasping thereof during
12 installation, the attachment plate 22 being shown with upper and lower through holes
13 aligned with upper and lower through holes of sparger end plate 16.

14 A representative side plate 24 has a straight rearward edge in facing abutment with
15 a forward surface of the attachment plate 22. A weld 27 is disposed between the abutting
16 surfaces of the side plate 24 and the attachment plate 22 and thusly connects the side
17 plate to the attachment plate. The side plate 24 is connected to the attachment plate 22
18 at a location adjacent or close to the inner side edge of attachment plate 22. The side
19 plate 24 is planar and has a generally rectangular peripheral configuration with the major
20 dimension thereof extending vertically in the reactor vessel 12 and the minor dimension
21 thereof extending perpendicular to the attachment plate.

1 Representative upper and lower bracket members 25 and 26 are also planar, and
2 each bracket member has a straight rearward edge, a beveled forward edge, and parallel
3 inner and outer straight side edges connecting the forward and rearward edges. The
4 rearward edges of the upper and lower bracket members 25 and 26 are each in facing
5 abutment with the forward surface of attachment plate 22, with the bracket members 25
6 and 26 being perpendicular to the side plate 24 and to the attachment plate 22. Welds
7 28 connect the abutting surfaces of the upper and lower bracket members 25 and 26,
8 respectively, and the attachment plate 22. The straight inner side edge of each bracket
9 member is in abutting relation with an outer surface of the side plate 24, and welds 29
10 connect the abutting surfaces of the upper and lower bracket members 25 and 26,
11 respectively, and the side plate 24. The upper and lower bracket members 25 and 26 are
12 parallel to and vertically spaced from one another to closely accommodate the reactor
13 vessel attachment fitting 21 between a lower surface of the upper bracket member 25 and
14 an upper surface of the lower bracket member 26. Accordingly, the inner side edge of
15 upper bracket member 25 is connected to the side plate 24 at a location adjacent or close
16 to an upper edge of side plate 24, and the inner side edge of lower bracket member 26 is
17 connected to the side plate 24 at a location adjacent or close to a lower edge of the side
18 plate 24.

19 The representative feedwater sparger end bracket assembly 20 also includes a pin
20 30, extending through the upper and lower bracket members 25 and 26 and through the
21 reactor vessel attachment fitting 21, by which the feedwater sparger end bracket assembly

1 is secured or pinned to the reactor vessel attachment fitting. The pin 30 extends in the
2 vertical direction transverse or perpendicular to the upper and lower bracket members 25
3 and 26, and is inserted through aligned passages in the upper and lower bracket members
4 and the reactor vessel attachment fitting 21. An upper end or head of the pin 30 is
5 disposed above the upper bracket member 25 and is sized and/or configured such that
6 the head cannot pass through the passage in the upper bracket member 25. The passages
7 in the upper and lower bracket members 25 and 36 are ordinarily oval or elliptical in cross-
8 section and have centers, respectively, located centrally between the inner and outer side
9 edges of the corresponding bracket member.

10 A pin retainer 32 is engaged with or secured to the upper bracket member 25 and,
11 as best seen in Figs. 1 and 2, includes a bridge 33 centered over the head of pin 30 and
12 a pair of legs 34 extending downwardly from opposite ends of bridge 33 to feet 35. The
13 bridge 33 bisects the head of pin 30, and the legs 34 are spaced from one another a
14 sufficient distance to accommodate the head of pin 30 therebetween. The representative
15 pin retainer 32 is located so that the bridge 33 is perpendicular to the attachment plate 22
16 and parallel to the upper bracket member 25, with the legs 34 extending perpendicular to
17 the bridge 33. The feet 35 extend outwardly from the legs 34, respectively, and are secured
18 to or engaged with the upper bracket member 25 to prevent removal of the pin 30 after it
19 has been inserted sequentially through the passage of the upper bracket member 25, the
20 passage of the reactor vessel attachment fitting 21 and the passage of the lower bracket
21 member 26. In a representative pin retainer 32, the feet 35 extend perpendicular to legs

1 34 such that the feet 35 are also perpendicular to the attachment plate 22. The
2 representative pin retainer 32 is formed from an elongated, planar strip of material of
3 relatively minimal thickness.

4 A pin bail 36 of the feedwater sparger end bracket assembly 20 has a generally
5 inverted U-shape straddling the head of pin 30. As best seen in Figs. 3 and 5, pin bail 36
6 includes a cross-piece 37 extending over bridge 33 perpendicular thereto and spaced,
7 parallel arms 38 extending downwardly from opposite ends of cross-piece 37 to tapered
8 or angled lower ends secured to the head of pin 30. The cross-piece 37 bisects the head
9 of pin 30 along an axis 90° to bridge 33, and the lower ends of arms 38 are secured to the
10 head of pin 30 at locations, respectively, along this axis. The representative pin bail 36 is
11 flat or planar with beveled outside corners joining the arms 38 to opposite ends of cross-
12 piece 37, the pin bail 36 being parallel to attachment plate 22 and perpendicular to both
13 the side plate 24 and the upper bracket member 25. The space between arms 38 defines
14 an opening through which the bridge 33 passes. The pin bail 36 may be used for grasping
15 to facilitate raising and lowering of pin 30 for insertion and/or removal through the aligned
16 passages in the upper and lower bracket members 25 and 26 and the reactor vessel
17 attachment fitting 21 when the pin retainer 32 is not secured in place on the upper bracket
18 member.

19 The reactor vessel attachment fitting 21 includes a base attached to the reactor
20 vessel wall 11 and a nose protruding interiorly from the base in the radial direction. The
21 nose is insertable between the upper and lower bracket members 25 and 26 when the pin

1 30 is removed from between the bracket members, and has a vertical dimension to fit
2 closely between the upper and lower bracket members. A vertical passage through the
3 nose is aligned with the aligned passages through the upper and lower bracket members
4 25 and 26, respectively. The pin 30 is inserted in the aligned passages, with insertion of
5 the pin being facilitated by the pin bail 36. The pin 30 is secured in place in the aligned
6 passages, thereby securing the feedwater sparger end bracket assembly 20 to the reactor
7 vessel attachment fitting 21. The pin 30 may be secured in place via a threaded
8 engagement or in any other suitable manner. The reactor vessel attachment fitting 21 can
9 be formed integrally, unitarily with the reactor vessel wall 11 or as a separate component
10 secured to the reactor vessel wall in any suitable manner, such as welding. The base of
11 fitting 21 may have a curved outer end surface in abutting relation with the curved surface
12 of the reactor vessel wall 11, and the curvature of the end surface preferably corresponds
13 to the curvature of the reactor vessel wall. The feedwater sparger end bracket assembly
14 20 defines a load path for transferring loads from the feedwater sparger 14 to the reactor
15 vessel attachment fitting 21 and the vessel wall 11.

16 An alternative representative feedwater sparger end bracket assembly for use with
17 the clamp of the present invention is illustrated in Fig. 6 at 120. The feedwater sparger
18 end bracket assembly 120 is similar to feedwater sparger end bracket assembly 20 except
19 that the feedwater sparger end bracket assembly 120 includes a shim plate 141 between
20 the sparger end plate 116 and the attachment plate 122. Shim plate 141 is interposed
21 between the forward surface of the sparger end plate 116 and the rearward surface of the

1 attachment plate 122. The representative shim plate 141 is planar and has a generally
2 rectangular peripheral configuration with a major dimension oriented vertically within the
3 reactor vessel, which is not shown in Fig. 6. The peripheral configuration of shim plate
4 141 is typically larger than the peripheral configuration of both the sparger end plate 116
5 and the attachment plate 122 so that both the sparger end plate and the attachment plate
6 are disposed within the peripheral configuration of the shim plate. The shim plate 141 has
7 a planar rearward surface in abutting relation with the forward surface of the sparger end
8 plate 116, and a weld 142 disposed between the abutting surfaces of the shim plate and
9 the sparger end plate connects the shim plate to the sparger end plate. The shim plate
10 141 has a planar forward surface in abutting relation with the rearward surface of the
11 attachment plate 122, and a weld 143 disposed between the abutting surfaces of the shim
12 plate and the attachment plate connects the shim plate to the attachment plate. The
13 additional welds 142 and 143 of the feedwater sparger end bracket assembly 120 present
14 additional potential sites for stress corrosion cracking and concomitant weld failure in the
15 feedwater sparger end bracket assembly 120.

16 From the above, it should be appreciated that the feedwater sparger end bracket
17 assemblies with which the clamp of the present invention may be utilized can include one
18 or more shim plates, such as shim plate 141, to achieve proper fit of the feedwater sparger
19 end bracket assembly with the corresponding reactor vessel attachment fitting. It should
20 be further appreciated that proper fit of the feedwater sparger end bracket assembly with
21 the corresponding reactor vessel attachment fitting may be achieved by varying the

thickness of the attachment plate and/or the thickness of the sparger end plate, with or without the use of one or more shim plates. Where a stock thickness for the attachment plate is not sufficient to allow proper fit of the feedwater sparger end bracket assembly with the reactor vessel attachment fitting, one or more shim plates will typically be utilized to make the necessary adjustments. The radial and vertical locations of the attachment plate relative to the sparger end plate may also be varied, as needed, to obtain the proper fit.

Since the reactor vessel for a typical boiling water reactor has a plurality of feedwater sparger end bracket assemblies, most typically eight feedwater sparger end bracket assemblies, it can be seen that the combined thickness of the sparger end plate and the attachment plate, including any shim plates, may vary. In other words, the thickness of the sparger/bracket junction, which includes the sparger end plate, the attachment plate and any shim plates, may not be the same for each feedwater sparger end bracket assembly of a boiling water reactor. The clamp of the present invention may be adapted for use on sparger/bracket junctions of different thicknesses, and may be used on originally installed feedwater sparger end bracket assemblies as well as replacement feedwater sparger end bracket assemblies.

The feedwater spargers of boiling water reactors may be sprung into place during installation such that there is a shear load on the feedwater sparger end welds and the feedwater sparger end bracket assembly welds. One instance in which feedwater spargers are sprung into place involves the installation of replacement feedwater spargers having flow baffles at the feedwater nozzles of the reactor vessel to eliminate thermal shock

1 conditions at the feedwater nozzles. In order for the flow baffles to work effectively, they
2 must remain essentially in contact with the reactor vessel wall. This is assured by the
3 feedwater spargers being sprung into place at installation, resulting in a load on each
4 feedwater sparger end bracket assembly of approximately 8,000 pounds. In the event of
5 a complete through wall crack of the weld between the conduit end and the sparger end
6 plate and/or the weld between the sparger end plate and the attachment plate, causing the
7 feedwater sparger end bracket assembly to become completely detached from the
8 feedwater sparger, the installation preload would be lost and the feedwater sparger would
not perform as designed.

A clamp 44 for feedwater sparger end bracket assemblies is illustrated alone in Figs. 7-12 and installed on the feedwater sparger end bracket assembly 20 in Figs. 13-20. The clamp 44 includes first and second clamp members 45 and 46, respectively, and a connector 47 such as an externally threaded bolt or screw adjustably connecting the first and second clamp members in spaced relation. First clamp member 45 is an upper clamp member, second clamp member 46 is a lower clamp member, and the connector 47 adjustably connects the upper and lower clamp members in vertical spaced relation. The connector 47 extends through vertically aligned bores in the upper and lower clamp members 45 and 46, respectively, and the bores may be threaded to threadably engage a thread on the connector 47. Alternatively or additionally to the bores being threaded, a threaded nut may be provided on an end of the connector 47. Untightening or unthreading connector 47 allows the clamp to be moved from a closed position shown in Figs. 7 and

1 8 to an open position in which the vertical spacing between the upper and lower clamp
2 members is increased, thereby allowing installation of the clamp over a feedwater sparger
3 end bracket assembly. If necessary, the connector 47 may be removed entirely from the
4 lower clamp member to facilitate installation of the clamp on the feedwater sparger end
5 bracket assembly as described further below. Tightening or threading connector 47 closes
6 the clamp to decrease or reduce the vertical spacing between the upper and lower clamp
7 members, thereby securing the clamp in the closed position on the feedwater sparger end
8 bracket assembly as described further below.

9 The upper clamp member 45 comprises a housing having a medial portion 48
10 between a forward extension 49 and a rearward extension 50 as shown in Fig. 7. The
11 medial portion 48 extends interiorly beyond the forward and rearward extensions 49 and
12 50, and the bore through which the connector 47 passes extends entirely through the
13 medial portion. The bore extends through the medial portion 48 in the vertical direction
14 and has a central longitudinal axis coaxial with the bore of lower clamp member 46. The
15 forward extension 49 has an L-shaped configuration with a radial extension portion and a
16 horizontal extension portion extending forwardly from the radial extension portion at a right
17 angle.

18 As best shown in Fig. 8, an internal compartment 51 is defined in the upper clamp
19 member 45 and is bounded at the top by a planar internal top wall 52, at the front by a
20 planar internal front wall 53, at the rear by a planar internal rear wall 54 opposing internal
21 front wall 53, at an inner side by a planar internal inner side wall 55, and at an outer side

1 by a planar impingement shield 56 opposing internal inner side wall 55. The internal front
2 and rear walls 53 and 54 are parallel and are perpendicular to internal top wall 52, internal
3 inner side wall 55 and impingement shield 56. The internal inner side wall 55 is parallel to
4 impingement shield 56, and both are perpendicular to internal top wall 52. The
5 compartment 51 is open at the bottom of the upper clamp member, and a mouth or
6 opening along the bottom of the upper clamp member provides communication with the
7 compartment.

8 The top of upper clamp member 45 has a stepped configuration with forward
9 extension 49 protruding above the medial portion 48 and the rearward extension 50.
10 Accordingly, the forward extension 49 has an external top wall 60 spaced upwardly from
11 an external top wall 61 of medial portion 48 and rearward extension 50. The bottom of
12 upper clamp member 45 has a stepped configuration so as to define a downwardly
13 protruding inner shoulder or protrusion 62 extending downwardly from lower surface 63
14 and recessed lower surface 64 of upper clamp member 45, and a downwardly protruding
15 outer shoulder or protrusion 65 extending downwardly from the lower surface 63. The
16 lower surface 63 is at the bottom of the upper clamp member and is a forward lower
17 surface located to the front of the opening into compartment 51. The recessed lower
18 surface 64 is at the bottom of the upper clamp member and is a rearward lower surface
19 located to the rear of the opening into compartment 51. The forward and rearward lower
20 surfaces 63 and 64 are planar and parallel to one another, and are perpendicular to the
21 internal front and rear walls 53 and 54, the internal inner side wall 55 and the impingement

1 shield 56. Also, the forward and rearward lower surfaces 63 and 64 are parallel to internal
2 top wall 52.

3 The inner shoulder 62 extends along an inner side of upper clamp member 45 in the
4 horizontal or tangential direction and extends between the front and rear walls of
5 compartment 51. The inner shoulder 62 has a planar outer surface 67, coextensive with
6 internal inner side wall 55, perpendicularly joined to the forward lower surface 63 to the
7 front of the opening into compartment 51 and perpendicularly joined to the rearward lower
8 surface 64 to the rear of the opening into compartment 51. The outer surface 67 of inner
9 shoulder 62 extends downwardly from the opening of compartment 51 and is perpendicular
10 to the internal front and rear walls 53 and 54. A shim pad 66 is secured on the outer
11 surface 67 of inner shoulder 62 and extends vertically between the rearward lower surface
12 64 and a bottom surface of inner shoulder 62. The shim pad 66 extends forwardly from
13 an external rear wall of medial portion 48 to terminate at a forward edge and has a depth
14 or thickness in the radial direction. The forward edge of shim pad 66 is spaced rearwardly
15 from the internal front wall 53 a sufficient distance for the thickness of the sparger/bracket
16 junction to be accommodated in the compartment 51 between the internal front and rear
17 wall 53 and 54. As best shown in Fig. 20 for the lower clamp member 46, a spacer 68
18 extends radially outwardly from the internal inner side wall 55 and may be secured to the
19 shim pad 66 and/or to the internal inner side wall 55. The distance that the spacer 68
20 extends radially outwardly from the internal inner side wall 55 is selected such that the

1 spacer limits the clearance between the upper clamp member 45 and the inner side wall
2 of the conduit of the feedwater sparger as explained further below.

3 The outer shoulder 65 extends along the horizontal extension portion of forward
4 extension 49 parallel to inner shoulder 62 and has a planar inner surface 70 extending
5 perpendicularly downwardly from the forward lower surface 63, the inner surface 70 being
6 parallel to the outer surface 67 of inner shoulder 62. The outer shoulder 65 extends along
7 the outer side of the upper clamp member opposite the inner side thereof and has a depth
8 in the radial direction between inner surface 70 and a planar external outer surface 71 of
9 forward extension 49. The outer surface 71 extends in a first direction, i.e. forwardly, from
10 the compartment 51 and forms part of the external outer side wall for the upper clamp
11 member 45. The depth of the outer shoulder 65 allows the outer shoulder to be
12 accommodated between the lower bracket member of a feedwater sparger end bracket
13 assembly and the reactor vessel wall as explained further below.

14 The radial extension portion of forward extension 49 includes a planar external
15 forward wall 72 perpendicularly joined to a planar external inner side wall 73 of the
16 horizontal extension portion at an inside corner. The forward wall 72 has a notch 74
17 therein adjacent the inside corner at which the forward wall 72 is joined to the inner side
18 wall 73. The forward wall 72 is perpendicularly joined to the forward lower surface 63
19 along a lower edge of the forward extension, and the notch 74 is located along the lower
20 edge of the forward extension. The notch 74 is open at the front and at the bottom of the
21 radial extension portion. The inner side wall 73 of the horizontal extension portion is

1 parallel to the inner surface 70 of outer shoulder 65 and has a cavity 75 therein of generally
2 rectangular cross-section. The inner side wall 73 is joined to the inner surface 70 of outer
3 shoulder 65 by the forward lower surface 63, the inner side wall 73 being joined to forward
4 lower surface 63 along the lower edge of the forward extension. The cavity 75 is open
5 along the inner side and bottom of the horizontal extension portion, the cavity 75 being
6 open along a lower edge of the horizontal extension portion at which the inner side wall 73
7 is perpendicularly joined to the forward lower surface 63. The rearward lower surface 64
8 is recessed upwardly relative to the forward lower surface 63 so that the rearward lower
9 surface 64 is recessed upwardly from the bottom surface of inner shoulder 62 a greater
10 distance than the forward lower surface 63 is recessed upwardly from the bottom surface
11 of the inner shoulder.

12 The rearward extension 50 is connected to the medial portion 48 at a curved inside
13 corner and includes a straight horizontal segment extending rearwardly in the horizontal
14 direction in alignment with the horizontal extension portion of forward extension 49. The
15 horizontal segment of rearward extension 50 has an external outer side wall 77
16 coextensive with a downwardly protruding shear tab or protrusion 79 which protrudes
17 downwardly from the rearward lower surface 64 along the outer side of the upper clamp
18 member. The outer side wall 77 forms part of the external outer side wall for the upper
19 clamp member and includes a rearward outer side wall segment along shear tab 79 and
20 a forward outer side wall segment extending forwardly from shear tab 79 to impingement
21 shield 56. The forward and rearward outer side wall segments are planar, with the forward

1 outer side wall segment recessed inwardly from the rearward outer side wall segment.
2 The shear tab 79, which is parallel to inner shoulder 62, begins at an external rear wall of
3 the rearward extension 50 and extends forwardly therefrom along part of the horizontal or
4 tangential length of the outer side of rearward extension 50. Accordingly, the shear tab 79
5 is spaced from compartment 51 in a second direction, i.e. rearwardly, opposite the direction
6 of extension for outer shoulder 65 such that the inner shoulder 62 is located between the
7 outer shoulder 65 and the shear tab 79 but is disposed closer to the outer shoulder than
8 to the shear tab. The shear tab 79 has a planar outer side surface 78 formed by the
9 rearward outer side wall segment and an inner side surface 80 parallel to the outer side
10 surface 78. The inner side surface 80 is parallel to the outer surface 67 of inner shoulder
11 62 and is joined to the outer side surface 78 at a tapered lower end of the shear tab 79.
12 The shear tab 79 has a depth or thickness in the radial direction between the outer side
13 surface 78 and the inner side surface 80 and has a location rearward of the compartment
14 51 to fit between the outer side wall of the feedwater sparger conduit 15 and the reactor
15 vessel wall 11 with a close fit as explained below.

16 The impingement shield 56 may be formed integrally, unitarily with the housing of
17 the upper clamp member 45 or as a separate compartment attached to the housing in any
18 suitable manner. The impingement shield 56 is illustrated as a separate component bolted
19 or screwed to the housing. The impingement shield 56 extends vertically from the top of
20 the upper clamp member 45 to a straight, horizontal lower end 82 best shown in Fig. 9.
21 The impingement shield 56 is planar and has a depth or thickness between planar and

parallel inner and outer shield surfaces, the outer shield surface being flush or substantially flush with the forward outer side wall segment of rearward extension 50. The lower end 82 of the impingement shield is of reduced thickness to overlap an upper end of an impingement shield for the lower clamp member 46 as explained further below. The impingement shield 56 completes the external outer side wall of upper clamp member 45 and extends from the outer side wall 77 of rearward extension 50 to the outer surface 71 of forward extension 49 such that the compartment 51 is closed off along the outer side of the upper clamp member. The impingement shield 56 extends vertically below the bottom surface of inner shoulder 62 a sufficient distance to meet the impingement shield of the lower clamp member in the closed position for clamp 44 as described below.

The lower clamp member 46 is essentially a mirror image of upper clamp member 45 and comprises a housing having a medial portion 83 between a forward extension 84 and a rearward extension 85 as shown in Fig. 7. The medial portion 83 extends interiorly beyond the forward and rearward extensions 84 and 85, and has an external inner side wall including a top portion and a bottom portion angled downwardly from the top portion in the outward direction to meet the bottom wall of the lower clamp member. The bore in lower clamp member 46 through which the connector 47 passes extends entirely through medial portion 83 in the vertical direction. The forward extension 84 has an L-shaped configuration with a radial extension portion and a horizontal extension portion perpendicular to the radial extension portion thereof.

1 An internal compartment 86, best shown in Figs. 7 and 8, is defined in the lower
2 clamp member 46 as a counterpart to compartment 51 of the upper clamp member 45.
3 Internal compartment 86 is similar to compartment 51 and is bounded at the bottom by a
4 planar internal bottom wall 87 which is parallel to internal top wall 52, at the front by a
5 planar internal front wall 88 which is co-planar with internal front wall 53, at the rear by a
6 planar internal rear wall 89 which is co-planar with internal rear wall 54, at the inner side
7 by a planar internal inner side wall 90 which is co-planar with internal inner side wall 55,
8 and at the outer side by a planar impingement shield 91 which is co-planar with
impingement shield 56. The compartment 86 is open at the top of the lower clamp
member and has a mouth or opening along the top of the lower clamp member providing
communication with the compartment 86. The opening of compartment 86 is in facing
relation to the opening of compartment 51 and is vertically aligned therewith.

1 The bottom of lower clamp member 46 is defined by a planar external bottom wall.
2 The top of lower clamp member 46 has a stepped configuration defining an upwardly
3 protruding inner shoulder or protrusion 94 extending upwardly from planar upper surface
4 95 and planar recessed upper surface 96, and an upwardly protruding outer shoulder or
5 protrusion 97 extending upwardly from the upper surface 95. The upper surface 95, which
6 is at the top of the lower clamp member, is located to the front of the opening into
7 compartment 86 and is a forward upper surface. The recessed upper surface 96 is located
8 to the rear of the opening into compartment 86 at the top of the lower clamp member and
9 is a rearward upper surface. The forward upper surface 95 corresponds to the forward

1 lower surface 63 and is parallel to and vertically aligned with the forward lower surface 63.
2 The rearward upper surface 96 corresponds to the rearward lower surface 64 and is
3 parallel to and vertically aligned with the rearward lower surface 64.

4 The inner shoulder 94 is similar to the inner shoulder 62 and is vertically aligned
5 with the inner shoulder 62. The inner shoulder 94 extends along the inner side of lower
6 clamp member 46 in the tangential or horizontal direction between the front and rear walls
7 of compartment 86 and has a planar outer surface 98 coextensive with internal inner side
wall 90, the outer surface 98 being perpendicular to the internal front and rear walls 88
and 89. The outer surface 98 of inner shoulder 94 is perpendicularly joined to forward
upper surface 95 to the front of the opening of compartment 86 and is perpendicularly
joined to rearward upper surface 96 to the rear of the opening into compartment 86. The
outer surface 98 extends upwardly from the opening of compartment 86 and is co-planar
with the outer surface 67 of the inner shoulder 62. A shim pad 66 is secured on the outer
surface 98 as described above for the upper clamp member 45 and is located at a location
15 corresponding to the shim pad 66 of the upper clamp member. The shim pad 66 of the
16 lower clamp member 46 thusly extends vertically between the rearward upper surface 96
17 and a top surface of inner shoulder 94. A spacer 68, shown in Fig. 20, extends radially
18 outwardly from the internal inner side wall 90 as described above for the spacer 68 of the
19 upper clamp member. The spacer 68 for the lower clamp member is disposed at a location
20 corresponding to the location for the spacer of the upper clamp member.

The outer shoulder 97 is similar to the outer shoulder 65 and is vertically aligned with the outer shoulder 65. The outer shoulder 97 extends along the horizontal extension portion of forward extension 84 parallel to the inner shoulder 94 and has a planar inner surface 99 extending perpendicularly upwardly from the forward upper surface 95. The inner surface 99 of outer shoulder 97 is parallel to the outer surface 98 of inner shoulder 94, and is co-planar with the inner surface 70 of the outer shoulder 65 of the upper clamp member 45. The outer shoulder 97 extends along the outer side of the lower clamp member in the forward direction from compartment 86, and has a depth in the radial direction between inner surface 99 and a planar external outer surface 100 of the forward extension 84. The outer surface 100 forms part of the external outer side wall for the lower clamp member. The top of outer shoulder 97 and the bottom of outer shoulder 65 may have beveled or chamfered edges.

The radial extension portion of forward extension 84 includes a planar external forward wall 101 joined to a planar external inner side wall 102 of the horizontal extension portion by an angled corner wall. The forward wall 101, the corner wall and the inner side wall 102 are perpendicularly joined to the forward upper surface 95 along an upper edge of the forward extension 84. The rearward upper surface 96 is recessed downwardly relative to the forward upper surface 95 so that the rearward upper surface 96 is recessed downwardly from the top surface of inner shoulder 94 a greater distance than the forward upper surface 95 is recessed downwardly from the top surface of the inner shoulder 94.

1 The rearward extension 85 is similar to rearward extension 50 and is vertically
2 aligned with the rearward extension 50. The rearward extension 85 has a horizontal
3 segment corresponding to the horizontal segment of rearward extension 50 and has an
4 external outer side wall 103 coextensive with an upwardly protruding shear tab or
5 protrusion 105. The outer side wall 103 forms part of the external outer side wall for the
6 lower clamp member and includes a rearward outer side wall segment along shear tab 105
7 and a forward outer side wall segment extending forwardly from shear tab 105 to
impingement shield 91, with the forward outer side wall segment being recessed inwardly
from the rearward outer side wall segment. Shear tab 105 is similar to shear tab 79 and
protrudes upwardly from the rearward upper surface 96, the shear tab 105 being disposed
at a location corresponding to the location of shear tab 79. Accordingly, the shear tab 105
is spaced from compartment 86 in the rearward direction, opposite the direction of
extension for outer shoulder 97, such that the inner shoulder 94 is located between the
outer shoulder 97 and the shear tab 105 but is disposed closer to the outer shoulder 97
than to the shear tab 105. The shear tab 105 has a planar outer side surface 104 formed
by the rearward outer side wall segment of outer side wall 103 and has an inner side
surface 106 parallel to the outer side surface 104. The inner side surface 106 is parallel
to the outer surface 98 of inner shoulder 94 and is joined to the outer side surface 104 at
a tapered upper end for the shear tab 105 as described for the shear tab 79. The outer
side surface 104 of shear tab 105 is co-planar with the outer side surface 78 of shear tab

1 79. The inner side surface 106 of shear tab 105 is co-planar with the inner side surface
2 80 of shear tab 79.

3 The impingement shield 91 is similar to impingement shield 56 and extends in the
4 vertical direction from the bottom of the lower clamp member 46 to a straight, horizontal
5 upper end 107 best shown in Fig. 9. The upper end 107 is of reduced thickness to
6 overlap the lower end 82 of impingement shield 56 when the clamp 44 is in the closed
7 position as shown in Fig. 9. With the clamp in the closed position, the planar inner surface
8 of shield 56 is flush or substantially flush with a planar inner surface of shield 91, and the
9 planar outer surface of shield 56 is flush or substantially flush with a planar outer surface
10 of shield 91. The impingement shield 91 completes the external outer side wall of lower
11 clamp member 46 and extends from the outer side wall 103 of rearward extension 85 to
12 the outer surface 100 of forward extension 84 such that the compartment 86 is closed off
13 along the outer side of the lower clamp member. The impingement shield 91 extends
14 upwardly above the top surface of inner shoulder 94 such that the upper edge 107
15 engages the lower edge 82 of impingement shield 56 when the clamp 44 is in the closed
16 position.

17 The clamp 44 is preferably fabricated primarily from Austenitic 300 series stainless
18 steel. If additional material strength is needed for certain components, XM-19 stainless
19 steel may be used. In a preferred embodiment, the upper and lower clamp members each
20 have a maximum horizontal or tangential dimension of about 16.60 inches and a maximum
21 radial dimension of about 7.75 inches. The upper clamp member has a maximum vertical

1 dimension or height of about 8.00 inches, and the lower clamp member has a maximum
2 vertical dimension or height of about 6.5 inches. The connector is about 1.25 inches in
3 diameter with seven threads per inch and is about 15 inches long including the head
4 thereof.

5 A method of preventing separation of feedwater sparger end bracket assemblies
6 involves installing the clamp assembly 44 on a feedwater sparger end bracket assembly,
7 such as feedwater sparger end bracket assembly 20, with the clamp being lowered into the
128 reactor vessel 12 using remote tooling. The upper and lower clamp members are moved
129 away from one another and are separated vertically to the extent required to obtain an
130 open position for the clamp, allowing the clamp members to fit over the feedwater sparger
131 and the feedwater sparger end bracket assembly. The upper clamp member 45 is
132 disposed over the top of the sparger/bracket junction, and the lower clamp member 46 is
133 disposed below the sparger/bracket with the connector 47 located interiorly of the
134 feedwater sparger 14 and the feedwater sparger end bracket assembly 20. Accordingly,
135 the upper and lower clamp members will be disposed in opposition to one another over the
136 feedwater sparger end bracket assembly. An upper portion of the sparger/bracket
137 junction, i.e. upper portions of sparger end plate 16 and attachment plate 22 which
138 protrude upwardly beyond the conduit 15 and the upper bracket member 25, is aligned with
139 the internal compartment 51 of the upper clamp member 45. A lower portion of the
140 sparger/bracket junction, i.e. lower portions of sparger end plate 16 and attachment plate
141 22 which protrude downwardly beyond the conduit 15 and the lower bracket member 26,

is aligned with the internal compartment 86 of lower clamp member 46. Of course, where the sparger/bracket junction includes a shim plate, an upper portion of the shim plate will be aligned with compartment 51 and a lower portion of the shim plate will be aligned with compartment 86. The connector 47 is then threaded into the lower clamp member, and the connector 47 and/or another tool is used to move the upper and lower clamp members 45 and 46 toward one another. The upper and lower clamp members 45 and 46 are drawn together to obtain the closed position in which the clamp members enclose the upper and lower portions of the sparger/bracket junction. The upper and lower clamp members are securely tightened on the feedwater sparger 14 and the feedwater sparger end bracket assembly 20, and are held in place via the connector 47. The clamp 44 will then be in a closed position with the lower end 82 of impingement shield 56 in overlapping engagement with the upper end 107 of impingement shield 91. The clamp is then left in place in the reactor vessel 12.

Figs. 13 - 20 illustrate the clamp 44 installed on the feedwater sparger end bracket assembly 20 to form a constrained feedwater sparger end bracket assembly, it being noted that the upper clamp member 45 is not shown in Fig. 20. With the clamp 44 installed on the feedwater sparger end bracket assembly 20, the upper portions of sparger end plate 16 and attachment plate 22 are disposed within the compartment 51 of the upper clamp member 45, and the lower portions of sparger end plate 16 and attachment plate 22 are disposed within the compartment 86 of lower clamp member 46. The leg 34 and/or foot 35 of pin retainer 32 disposed closest to the attachment plate 22 is accommodated in the

1 notch 74. An outer side of pin bail 36 is accommodated in the cavity 75. The upper
2 portions of sparger end plate 16 and attachment plate 22, i.e. the upper portion of the
3 sparger/bracket junction, are constrained in a first or horizontal or tangential direction
4 between the internal front wall 53 and the internal rear wall 54 of compartment 51 with a
5 close fit, i.e. with minimal or no clearance therebetween. The lower portions of sparger end
6 plate 16 and attachment plate 22, i.e. the lower portion of the sparger/bracket junction, are
7 constrained in the horizontal or tangential direction with a close fit between the internal
8 front wall 88 and the internal rear wall 89 of compartment 86. Separation of the feedwater
9 sparger end bracket assembly 20 from the end of the feedwater sparger 14 in a horizontal
10 or tangential direction is thusly prevented.

The sparger/bracket junction is constrained in a second or vertical direction due to
constraint of the sparger end plate 16 and the attachment plate 22 between the internal
top wall 52 of the upper clamp member 45 and the internal bottom wall 87 of the lower
clamp member 46. The upper and lower bracket members 25 and 26 are constrained in
the vertical direction with a close fit between the forward lower surface 63 of the upper
clamp member 45 and the forward upper surface 95 of the lower clamp member 46. The
feedwater sparger conduit 15 is constrained in the vertical direction with a close fit between
the rearward lower surface 64 of upper clamp member 45 and the rearward upper surface
96 of lower clamp member 46. Accordingly, separation of the feedwater sparger end
bracket assembly is prevented in the vertical direction.

The outer shoulder 65 of upper clamp member 45 is disposed between the upper bracket member 25 and the reactor vessel wall 11, with the inner surface 70 of outer shoulder 65 disposed adjacent the outer side edge of the upper bracket member with little or no clearance. The shear tab 79 of the upper clamp member 45 is disposed between the conduit 15 and the reactor vessel wall 11 with a close fit, the inner side surface 80 of the shear tab 79 being adjacent the outer side wall of the conduit with little or no clearance therebetween. The outer shoulder 97 of the lower clamp member 46 is disposed between the lower bracket member 26 and the reactor vessel wall 11, with the inner surface 99 of the outer shoulder 97 adjacent the outer side edge of the lower bracket member with little or no clearance therebetween. The shear tab 105 of the lower clamp member 46 is disposed between the conduit 15 and the reactor vessel wall 11 with a close fit, with the inner side surface 106 of the shear tab 105 adjacent the outer side wall of the conduit with little or no clearance therebetween. The outer surface 67 of inner shoulder 62 of the upper clamp member 45 is adjacent the inner side edge of attachment plate 22 with minimal or no clearance therebetween to establish a tight fit between the upper clamp member and the feedwater sparger end bracket assembly. The shim pad 66 of the upper clamp member 45 fills the gap or space between the outer surface 67 and the inner side wall of conduit 15 to establish a tight fit between the upper clamp member and the feedwater sparger. The spacer 68 of the upper clamp member 45 occupies the gap or space between the outer surface 67 and the inner side edge of the sparger end plate 16 as shown in Fig. 20 for the lower clamp member, thereby further ensuring a tight fit between

the upper clamp member and the feedwater sparger. The lower clamp member 46 is installed on the feedwater sparger and bracket assembly in the same manner as the upper clamp member. The outer surface 98 of inner shoulder 94 of the lower clamp member 46 is adjacent the inner side edge of attachment plate 22, and the shim pad 66 of the lower clamp member fills the gap or space between the outer surface 98 and the inner side wall of conduit 15. The spacer 68 of the lower clamp member 46 occupies the gap or space between the outer surface 98 and the inner side edge of the sparger end plate 16 as shown in Fig. 20. Separation of the feedwater sparger end bracket assembly 20 is prevented in the radial direction due to the feedwater sparger end bracket assembly being constrained with a close fit between the inner shoulders 62, 94 and the outer shoulders 65, 97. Also, the feedwater sparger 14 is constrained in the radial direction due to constraint of conduit 15 between the inner shoulders 62, 94 and the outer shoulder 65, 97 via the shim pads 66 and due to radial constraint of the conduit 15 between the inner shoulders 62, 94 and the shear tabs 79, 105 via the shim pads 66.

The impingement shields 56, 91 are disposed between the sparger/bracket junction and the reactor vessel wall 11. The impingement shields 56, 91 isolate the sparger/bracket junction from the vessel wall 11 and prevent direct impingement of feedwater flow on the reactor vessel wall 11 should a through wall crack develop between the conduit 15 and the sparger end plate 16. Accordingly, direct impingement of relatively colder feedwater on the reactor vessel wall 11 with concomitant thermal shock and cracking of the cladding on the interior surface of the reactor vessel wall is avoided. The shear tabs 79, 105 assist in

1 carrying moment on the clamp 44 that occurs in the event of a complete through wall crack
2 of the welds between the conduit 15 and the sparger end plate 16 or between the sparger
3 end plate 16 and the attachment plate 22. In the event that the feedwater spargers are
4 sprung into place such that there is a shear preload on the welds, the preload is
5 maintained by the clamp 44 in the event of weld failure. If either of the welds between the
6 conduit 15 and the sparger end plate 16 or between the sparger end plate 16 and the
7 attachment plate 22 fails, the load from the feedwater sparger is transferred to the clamp
44 at location A shown in Fig. 20. The clamp 44 reacts to this load at location B, and the
couple created by the loads at locations A and B creates a moment that must be balanced.
The shear tabs 79, 105 react, at location C, to the couple created by the loads at locations
A and B such that all loads and moments are balanced. Accordingly, the outer shoulders
65, 97 and the shear tabs 79, 105 cooperate with the inner shoulders 62, 94 to place the
clamp and the feedwater sparger in equilibrium. Since the installation preload is
transferred to and maintained by the clamp 44, flow baffles of the feedwater sparger will
remain essentially in contact with the reactor vessel wall.

16 Various shims and spacers can be incorporated in the clamp 44 to achieve a tight
17 fit between the clamp and the feedwater sparger and/or the feedwater sparger end bracket
18 assembly, as needed. Various shims and spacers can be incorporated in the clamp 44
19 to adapt the clamp for installation on feedwater sparger end bracket assemblies having
20 various dimensions and components. The clamp can be installed on feedwater sparger
21 end bracket assemblies having one or more shim plates, such as feedwater sparger end

1 bracket assembly 120, by forming the internal compartments 51, 86 with a distance
2 between the internal front walls and the internal rear walls sufficient to accommodate the
3 sparger end plate, the attachment plate, and any shim plate. A clamp designed for
4 installation on feedwater sparger end bracket assembly 120 can also be installed on the
5 feedwater sparger end bracket assembly 20 by using shims and/or spacers to achieve a
6 close fit between the feedwater sparger end bracket assembly 20 and the clamp. It should
7 be appreciated, therefore, that the clamp 44 can be used on sparger/bracket junctions of
8 different thicknesses. The shims and/or spacers can be incorporated in the clamp at any
9 suitable locations.

10 The clamp 44 positively secures to the feedwater sparger end bracket assembly and
11 holds the feedwater sparger and the feedwater sparger end bracket assembly together in
12 the event of through wall cracking of any or all feedwater sparger and/or feedwater sparger
13 end bracket assembly welds. The clamp prevents separation of the feedwater sparger end
14 bracket assembly in first, second and third directions, i.e. horizontal or tangential, vertical
15 and radial directions. The clamp prevents separation of the feedwater sparger end bracket
16 assembly from the feedwater sparger and prevents separation of the structural
17 components of the feedwater sparger end bracket assembly. The clamp provides an
18 alternate load path for loads from the feedwater sparger to the reactor vessel attachment
19 fitting, and the outer shoulders and shear tabs provide an alternate path for transferring
20 loads from the feedwater sparger to the reactor vessel attachment fitting. The clamp can
21 be installed remotely from a refueling bridge using long-handled tooling. The clamp

1 incorporates corrosion resistant materials and does not require welding to the feedwater
2 sparger, the feedwater sparger end bracket assembly or to the reactor vessel.

3 In as much as the present invention is subject to many variations, modifications and
4 changes in detail, it is intended that all subject matter discussed above or shown in the
5 accompanying drawings be interpreted as illustrative only and not be taken in a limiting
6 sense.